

DISTRIBUTION OF RAT SPECIES (*RATTUS* SPP.) ON THE ATOLLS OF THE MARSHALL ISLANDS: PAST AND PRESENT DISPERSAL

by

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INTRODUCTION

The study of dispersal processes of small mammals, and especially of rodents, has a wide range of applications and until recent years there were few publications discussing the colonisation of 'oceanic' islands by small mammals (cf. Crowell, 1986; Diamond, 1987; Hanski, 1986; Heany, 1986; Lomolino, 1986).

This essay will be concerned with the distribution of rat species in the Marshall Islands and its implications on the interpretation of the settlement and human use of the atolls. It will be argued that in all instances the introduction of rats was caused by people and that accidental transport, such as rafting on drift wood and the like, is as unlikely as introduction by means of ship wrecks. Human transport as well as the rats' own inability to cross great distances of water makes them bad zoogeographical markers, as already pointed out by Braestrup (1956), but it is precisely this trait that is of concern here. This paper will argue that the Polynesian rat (*Rattus exulans*) was an intentional introduction to the area and that its distribution throughout the Marshall Islands was a deliberate strategy.

THE MARSHALL ISLANDS

The Marshall Islands (*Aeon Kein Ad*), comprising 29 atolls and 5 islands, are located in the northwest equatorial Pacific, about 3790km west of Honolulu, about 2700km north of Fiji and 1500km east of Ponape. With the exception of the two northwestern atolls, Enewetak and Ujelang, the Marshall Islands are arranged in two island chains running roughly NNW to SSE: the western Ralik Chain and the eastern Ratak Chain (figure 1). Not counting the five islands, Jemo, Jabwat, Kili, Lib and Mejit, the atolls of the Marshall Islands range from very small, with less than 3.5km², such as Nadikdik (Knox) Atoll, to very large. With 2173km² lagoonal area, Kwajalein Atoll has the distinction to be the atoll with the World's largest lagoon. Distances between neighbouring atolls range from as little as 7nm (as in the case of Nadikdik and Mile) to over 400nm.

There is a range of rainfall regimes, ranging from almost 4000mm yr⁻¹ as measured on the southern atoll of Jaluit (5°47'N) to 1000mm yr⁻¹ as noted for the northern atoll of Wake (19°28'N). Concomitant with that comes a range of vegetation patterns with drier ecotones prevailing in the north. The lack of a permanent ground water lens (Ghyben-Herzberg lens)

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makes these atolls very marginal for human habitation. It is thus not surprising that these islands have been recorded as uninhabited in the past (cf. Spennemann, 1992). The question arises whether these islands were ever visited by the Marshallese, either on a temporary or a semi-permanent basis.

THE RAT SPECIES

Today, there are three rat species present in the Marshall Islands (table 1): the Polynesian rat (*Rattus exulans*), the European rat (*Rattus rattus*, 'black rat'), and the Norway rat (*Rattus norvegicus*). In addition, the house mouse (*Mus musculus*) is reputedly present on Majuro, Enewetak and possibly Kwajalein Atolls (Berry & Jackson, 1979). The pre-World War II rat population of the Marshall Islands, it seems, did not comprise *Rattus rattus* or *R. norvegicus*. Before we review the historic evidence, let us look at the dispersal mechanisms used by rats.

The Polynesian rat is a fairly sedentary animal with a limited home-range. Contrary to black rats (*Rattus rattus*), the Polynesian rat was not observed marking its territories (Tomich, 1970). It has a predominantly herbivorous diet (Bettesworth, 1972; Fall *et al.*, 1971) but has also been observed preying on insects (Harrison, 1954; Fall *et al.*, 1971), snails (Harrison, 1961), land crabs (Moseby *et al.*, 1973), lizards (Crook, 1973; Whitaker, 1973), turtle hatchlings (Balazas, 1983; Hoeck, 1984, p. 242), and bird eggs (Atkinson, 1978; Bourne, 1981; Norman, 1975).

While Polynesian rats can be a plague on European-style monoculture plantations (Bianchi & Smythe, 1965; Bonin, 1982, 1986; Canter Visscher, 1957; Friend, 1971; Halafihi, 1985; Pierce, 1971a, 1971b; Twibell, 1973; Williams, 1974, 1975, 1982; Williams & Misikini, 1972; Wodzicki, 1969), they were little problem in the horticultural framework of the Marshallese culture. Indeed, Chamisso (1986) mentions that the number of rats had already increased in the period between his first (1816) and second visit (1817) to Wotje Atoll, destroying most of the plants planted in a model garden. Thus it was decided to leave behind a number of cats.

It has been put forward that *Rattus exulans* is responsible for the decline of the lizard fauna in New Zealand and beyond (Crook, 1973; Morrison, 1954, p. 4; Whitaker, 1973, 1978). Elsewhere it had been argued (Spennemann, 1989, p. 142) that this fact might explain the observed extinction of large lizard species after initial human settlement of oceanic islands (Poulsen, 1987; Pregill & Dye, 1989).

Traditionally, that is before the arrival of the first European visitors, the 'bird atolls' of Jemo, Taka, Bikar and Bokak had been regarded as refuges where the taking of birds and eggs has been tightly regulated by custom (Erdland, 1914; Fosberg, 1957; Tobin, 1952). The fact that the bird populations continue to thrive (Amerson, 1969; Thomas, 1989) may indicate that the presence of *Rattus exulans* is not detrimental to the overall bird population.

Both *R. rattus* and *R. norvegicus* are omnivorous and take whatever food is available. In addition, both species are on the whole substantially more carnivorous than *R. exulans* and have been shown to prey not only on insects, but also on bird eggs, bird fledglings, lizards,

land snails, molluscs, turtle hatchlings, and land crabs (Atkinson, 1978; Austin, 1948; Bailey & Sorensen, 1962; Bettesworth & Anderson, 1972; Crook, 1973; Daniel, 1973; Fall *et al.*, 1971; Harrison, 1961; Ramsay, 1978; Swink *et al.*, 1970; Watts & Aslin, 1982; Whitaker, 1973, 1978). The two larger species are also known to displace *R. exulans* from their environmental niche (Atkinson, 1973). Once established the rats have been shown to be quite resilient against natural disasters, being able to survive at least short-time flooding of an island by storm surges (as evidenced by the tidal surge generated by the Enewetak nuclear tests; Jackson, 1969).

A local example of the impact of introduced rats comes from Wake Atoll (Eneen-Kio), where the most dominant mammal on the atoll was the Polynesian rat. During the Japanese period of occupation in World War II the *R. rattus* was introduced (Bryan, 1959). The original bird life consisted of about a dozen different species of sedentary sea birds, and a few species of migratory sea birds. The only nonmigratory land bird native to and only occurring on Wake was the flightless rail, *Rallus wakensis*, which was still seen by the Tanager expedition in 1922, but which is now presumed to be extinct (Bryan, 1959). Given the introduction of shipborne rats in Japanese times an eradication of the rail by predatory rats possibly coupled with human predation appears to be the most likely explanation of its extinction.

DISPERSAL OF RATS

The dispersal of small mammals over greater and smaller expanses of water is thought to have happened in three basic ways:

- i) by accidental rafting on material floating in the water (such as tree trunks, logs, islands of vegetation, and other debris);
- ii) by swimming; and finally
- iii) by human-induced transport on boats, ships and rafts.

In the cold climates of the high latitudes movement over frozen lakes and the like, as well as rafting on ice floats, is also possible (cf. Lomolino, 1986). Accidental rafting on debris depends entirely on the direction of wind and surface currents and can thus be assessed by the means of computer simulation studies (cf. Ward *et al.* 1973) as well as a review of documented drift voyages. In the Marshall Islands drift has been documented for the following places of origin: California, North America; Central Solomons; Japan; various atolls in central Kiribati; Krakatau, Indonesia; Maui, Hawaii; Palmyra Atoll, Line Islands, Kiribati; Philippines (?); Tulumán I., Bismarck Archipelago, PNG; and Lamotrek, Pingelap, Woleai and Yap in the Carolines, Federated States of Micronesia (Spennemann, 1996; in press). Internal drift has been documented for the Ratak atolls Mile and Mejit, in both cases reaching atolls in the Ralik Chain.

Dispersal of small terrestrial animals over long stretches of open water is impeded and rats have been shown to be unable to cover distances in excess of 2km on their own account (Jackson & Strecker, 1962; Spennemann & Rapp, 1987, 1989). Survival on drifting items over prolonged periods of time is also unlikely due to prolonged exposure to the tropical sun coupled with a lack of water and food. Another argument against successful large-scale

accidental dispersal of Polynesian rats on drift wood is the lack of this species on Johnston Atoll (Amerson & Skelton, 1976) and the French Frigate Shoals (Amerson, 1971), places which are not known to have had pre-European settlement at any time.

Thus, rats occurring on an isolated atoll are very likely to have been introduced at one point in time by people either intentionally or accidentally as stowaways. This has also been assumed previously by some authors (cf. Tate, 1935; Luomala, 1975). Parr (1941, p. 95) comments that the Polynesian rats on Wake Island were likely to come from wrecks or from "Polynesian" canoes. Unlike *R. rattus* and *R. norvegicus*, which are both known to be shipboard rats and thus could be accidental European or Asiatic import during the last two centuries, Polynesian rats are not known to infest vessels.

RATS AS A FOOD SOURCE

An unintentional human introduction of rats to the Marshall Islands is very unlikely, given the size of Marshallese voyaging canoes which were commonly about 18 to 20m long (exceptionally up to 30m) and had rather narrow hulls (Alessio, 1990; Browning, 1972; Chamisso, 1910, 1986; Erdland, 1914; Finsch, 1887; Hambruch, 1912; Hershheim, 1887; Krämer, 1905; Krämer & Nevermann, 1938). Given that size, then, rats would have been noticed if present. Rather, it would appear, rats were a welcomed source of food which – once released – could fend for itself and thus were taken along as deliberate introductions.

The Polynesian rat is believed to have originated in the Malayan region (Tate, 1935; Musser & Newcomb, 1983; Roberts, 1991), to have been spread by native canoes, and to have been deliberately introduced to many islands by Polynesians who considered it a valuable food source. There is archaeological evidence for pre-European distribution of *Rattus exulans* on other atolls and islands in the Pacific, such as Nukunono (Davidson, 1971); Kapingamarangi (Leach & Ward, 1981); Tikopia (Kirch & Yen, 1982, p. 277); Kiribati (Luomala, 1975), 'Eua, Tonga (Spennemann, 1987); Ha'apai, Tonga (Dye, 1987; Spennemann, 1988); Tongatapu, Tonga (Poulsen, 1987); Niutoputapu, Tonga (Kirch, 1988); and Easter Island (G.Clark pers.comm.).

In Tonga, Polynesian rats have been part of the diet (Gifford, 1929, p. 339; Martin, 1817, p. 279) and hunted for food and for entertainment (Martin, 1817, p. 279-283; Vason, 1810, p. 102-103). Polynesian rats have been seen on numerous now uninhabited islands, which have later on proven to have carried human occupation, eg. Henderson I. (Schubel & Steadman, 1989; Sinoto, 1983; Tate, 1935). In the Marshall Islands rats were eaten mainly by women. Chamisso, for example, observed rats being eaten on Wotje and Uterik in 1816/1817 (Chamisso, 1910, p. 169). Eating rats was common among several Pacific cultures where pigs (if present) and chicken were reserved for feasts and where terrestrial animal protein was rare. Eating rats, the only ubiquitous animals around, appears to have been a convenient means to provide protein for pregnant and lactating women.

DISTRIBUTION OF RATS IN THE MARSHALL ISLANDS

Overall the historic documentation of the rats is limited as they were never the focus of detailed study until after World War II.

Rattus exulans was observed on Wake (Eneen-Kio) possibly as early as 1568 is the identification of Wake or Bokak with Alvarez de Mendaña's San Francisco Island is correct (cf. Hezel, 1983, p. 29; Werstein, 1964, p. 13). *Rattus exulans* was also observed by the Russian Exploring Expedition of 1816/17 on Maloelap (Kaven), Wotje and Uterik (Chamisso, 1910, p. 169, 1986; p. 156). Chamisso comments that some informants claimed that the rat was nonexistent on Bikar Atoll. This should be read *cum grano salis* as Chamisso's informants' knowledge on the peripheral atolls was very limited at best, not very surprising in view of that fact that he was not a Marshallese but came from an atoll in the Western Carolines. It is of significance, however, that in Chamisso's opinion his informant Kadu could only think of the rats as a companion to people (Chamisso, 1910, p. 169).

Chamisso (1986, p. 156, 196) mentions that the number of rats had already increased in the period between his first (1816) and second visit (1817) to Wotje Atoll, destroying most of the plants he had planted in a model garden. Cats were released to act as vermin control, but by 1830, when Kotzebue returned to Wotje, the number had not diminished (Kotzebue, 1830, p. I 308).

The U.S. Exploring Expedition saw Polynesian rats in 1840 on then uninhabited Wake Island and collected some specimens (Cassin, 1858; Peale, 1848; Pickering, 1879; Poole & Schantz, 1942). The Tanager expedition in 1922 recorded only *Rattus exulans* for Wake (Picking, 1922), where they appear to have occurred in reasonable numbers. Following the establishment of the Pan American Airways station on Wake and the creation of open rubbish tips, Polynesian rats were to become a plague of major proportions and eventually were the focus of several eradication campaigns (Anonymous, 1941; Bryan, 1959; Devereux, 1947; Foulton, 1939; Grooch, 1936; Miller, 1936).

In the late 1880s, with the beginning of the German colonial administration, the number of scientific studies increased, mainly focussing on the avifauna, as rodents were seen as a pest (Anonymous, 1895) and not the focus of enquiry. As a side-effect of increased copra production the number of rats increased too. The German district Officer Georg Merz, stopping at Majuro Atoll in 1910 on occasion of his annual inspection voyage, reports on large numbers of rats in plague proportions and suggest the release of cats to reduce the rat problem (Merz 1910). The data in hand suggest that the pre-World War II rat population of the Marshall Islands comprised neither *Rattus rattus* or *R. norvegicus*, with the possible exception of Jaluit and Majuro Atolls, the former the administrative centre of the German and (later) Japanese Colonial Administrations, and the latter an atoll with a well established trading station replete with pier.

INTRODUCTION OF RATS, 1885 TO PRESENT

Inter-atoll communication in the Marshall Islands was previously upheld solely by the means of local canoe transport. Local communication between the atolls, however, seems to have been largely restricted to the southern part of both the Ralik and the Ratak chains, and between the southern parts and northern parts of either chain. An investigation of the distribution of introduced epidemics clearly documents this pattern. For example, Steinbach (1893), discussing the spread of a syphilis epidemic, mentions that it was prevalent in Majuro, Ebon and Jaluit Atolls but occurred only in limited proportions in the northern atolls, which had little communication with the former.

With the increasing presence of European traders, however, European vessels and even ship-/boat-building of European-type vessels, built by J.de Brum on Likiep Atoll, became more common. Conversely, the inter-atoll transport was increasingly conducted with larger, European-type vessels (*cf.* Linckens, 1912). During the period of the German colony, the Jaluit Gesellschaft operated a steam vessel as well as a number of sailing schooners in the islands. Further transport was provided by a vessel of the Australian Trading Company Burns Philp and Co. Apart from the inter-atoll trade, the Jaluit Gesellschaft also operated "long-distance" voyages to Pohnpei, Palau and New Guinea. In addition, there were the regular annual visits of German naval vessels. With the exception of Jaluit and Majuro none of the atolls had proper landing bridges or piers during the German period, and thus all vessels had to anchor in the lagoon with all trade being conducted by launch or canoe. The same applies to the few whalers that came in the 1880s to replenish their stores of water and food (Langdon, 1978, 1979).

Such conditions, however, are not at all conducive to the introduction of shipboard rats. The same pattern continued during the Japanese period until in the late, 1930 piers were built on islands earmarked for future military development (Yanaihara, 1940; Japanese Government, 1929).

The German government introduced quantities of soil to Jaluit to run the experimental garden. The import occurred mainly in the form of ship's ballast, brought by copra trading vessels returning partially empty from the volcanic high islands in the Carolines (such as Ponape) (*cf.* Anonymous, 1895; Fosberg, 1961; Fosberg & Sachet, 1962, p. 1; Stevenson, 1914, p. 150). It is possible that rats were also 'landed' during the unloading of these vessels.

The Japanese have a history of both unintentional and intentional introductions: during the period of Japanese administration import of soil directly from Japan has been reported (Price, 1935, p. 256). The Japanese, intent on staying for a long time, imported night soil from Japan to improve the soil on both Wake and Wotje Atolls (Kephardt, 1950, p. 34). Import of the same material can be assumed for two, or three other major Japanese bases, namely Kwajalein/Roi-Namur, Taroa (Maloelap Atoll) and Jaluit, all of which had been built before the begin of the Pacific War. These soil imports are likely to have been very small, just confined to gardening plots.

Table 1. The occurrence of *Varanus indicus* and the distribution of rodent species on the atolls of the Marshall Islands. [1]

Atoll	<i>Rattus exulans</i>	<i>Rattus rattus</i>	<i>Rattus norvegicus</i>	<i>Mus musculus</i>	Japanese Development	<i>Varanus indicus</i>
Ailinginae	■					
Ailinglaplap	?					
Ailuk	■					
Arno	■	■				
Aur	?					
Bikar	■					
Bikini	■					
Ebon	?					
Eneen-Kio [2]	■	■			major	
Enewetak	■	■ [3]		■	major	Present
Erikup	■					
Jabwat	■					
Jaluit	■	■	■	■	major	
Jamo	■					
Kili	?					
Kwajalein	■	■			major	Eradicated
Lae	■					
Lib	■					
Likiep	■					
Majuro	■	■	■	■	major	Eradicated
Maloelap	■	■			major	
Mejit	■					
Milli	■	■			major	
Nadikdik						
Namorik	■					
Namu	■					
Rongelap	■					
Rongerik	■					
Taka	■					
Taongi	■					
Ujae	■					
Ujelang	■					
Utirik	■					
Wotho	■					
Wotje	■	■ [4]			major	Eradicated (?)

[1] Compiled after Berry & Jackson 1970; Betlack & Eckhardt 1945; Bryan 1959; Cassin 1858; Chamisso 1886; Finsch 1893; Fosberg 1955, 1956; 1957, 1990; Gressitt 1961; Hatheway 1953; Kotzebue 1830; Marshall 1950; 1957; Thomas 1989; and own observations. [2] Wake Atoll in US parlance. [3] Introduced by the U.S. forces after 1944. [4] Introduced by the Japanese in the 1930s.

Apart from introducing plant pests along with the soil, the Brahminy blind snake (*Ramhotyphlos brahmina*, TYPHLOPIDAE) seems to have been introduced, occurring so far only on Enewetak Atoll (but there on different islands). The secretive, nocturnal and earth burrowing nature of this harmless snake makes its discovery a difficult (Lamberson, 1987).

During the Japanese occupation of Wake in World War II (Dec. 1941–Sept. 1945), *Rattus rattus* was introduced with devastating effects on the birdlife (Fosberg, 1959). Cunningham (1961, p. 87), Commanding Officer of the Wake I. garrison and commenting on the events of December 1941, mentions "*Wake Island's stunted rats*", which seems to refer to the Polynesian rat, suggesting that the black rat and the Norway rat had not yet arrived.

As these rats were present after the war, their import must have occurred during Japanese times. Already in the 1930s the Japanese had introduced the brown rat to Wotje (Marshall, 1950, p. 23) and Jaluit. While Marshall suggests that *R. rattus* may have been also introduced to Arno before the war, it is more likely that the landing boat activity of U.S. forces during the relocation of Marshallese from various Japanese-held atolls via Majuro to Tutu Island on Arno Atoll (Richard, 1957), is responsible for its introduction. The distribution of rat species in the Marshalls (table 1) shows that *R. rattus* and *R. norvegicus* are present on those atolls that were major Japanese military installations during World War II.

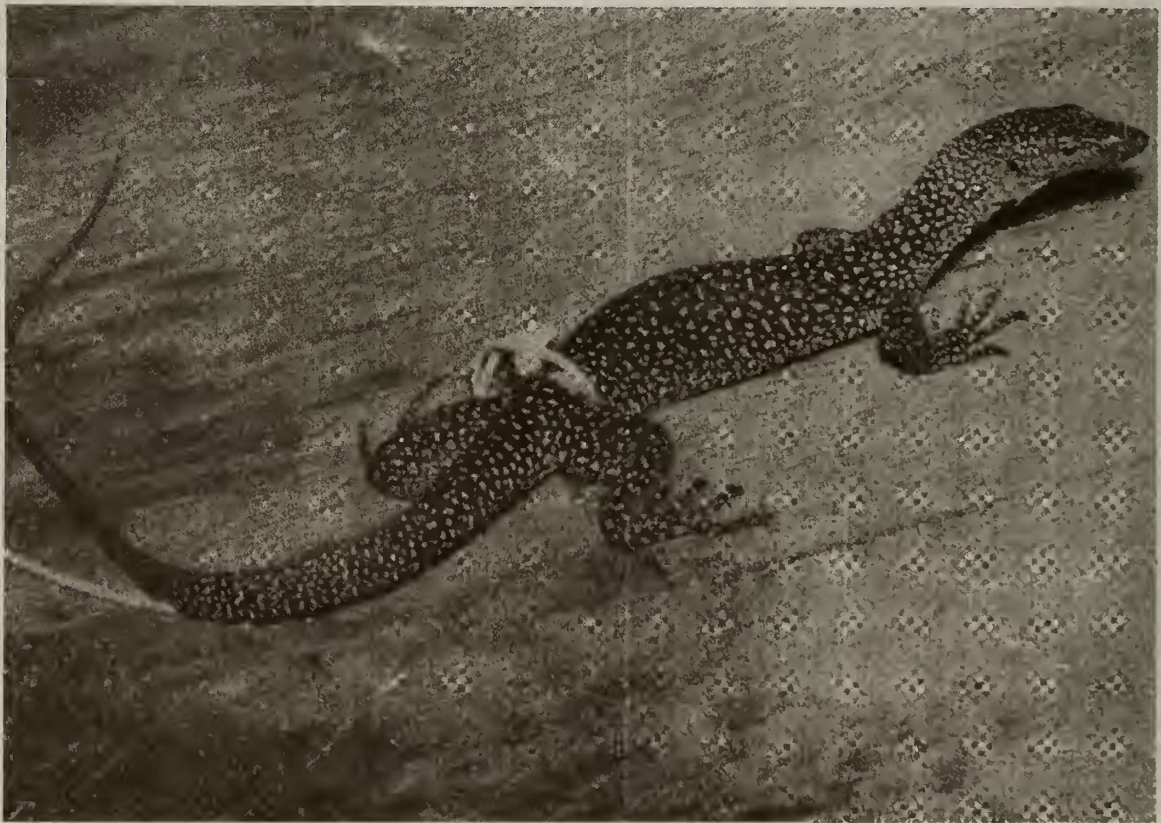


Figure 1. A specimen of *Varanus indicus* caught on Majuro Atoll, Marshall Islands during 1944/1945 (after Betlack & Eckhardt 1945).

The rat problem on some bases reached such proportions that *Varanus indicus* were introduced to prey upon the rats. Instead, according to local Marshallese informants, the reptiles preyed on the chickens as well as other birdlife. *Varanus indicus* has been described for Enewetak (Lamberson, 1987), where an extensive natural history assessment has been carried out. Immediately after the Pacific War it was found on Majuro when the US forces occupied the atoll (Betlack & Eckhardt, 1945). Today, *Varanus indicus* is occasionally caught on Enewetak and brought to the population centres of Majuro and Enewetak as a pet (pers. obs.).



Figure 2. A specimen of *Varanus indicus* caught on Enewetak Atoll and brought as a pet to Majuro Atoll, Marshall Islands (November 1992).

The distribution of the rat species in 1991/92, as shown in table 1, is based on a literature survey, as well as my own observations. The lack of *R.rattus/R.norvegicus* on most atolls is confirmed by own and other observations. Even though no trapping was carried out where *R.rattus/R.norvegicus* were present, such as on Taroa (Maloelap Atoll), Mile (Mile Atoll) and Wotje (Wotje Atoll) they were common and could be observed scurrying fearlessly on the ground. The rats permitted quite close observation before they ran away. This is also confirmed by members of the Independent Nationwide Radiological Study that took radioactivity measurements on all atolls of the Marshall Islands (Simon pers. comm). The current distribution of *R.rattus/R.norvegicus* is not an artifact of selective or differential observation and reporting.

POTENTIAL IMPACT OF SHIPBORNE RATS

Given the overall urban and agricultural/horticultural development of the atolls of the Marshall Islands the few bird atolls remain ecological refuges and sea-bird nesting colonies of Pacific-wide significance. Any landing of shipborne rats on board of a stricken vessel is likely to constitute an ecological catastrophe. And shipwrecks, especially of Japanese fishing vessels, are not uncommon (Spennemann, 1991; Thomas, 1989).

However, not all shipwrecks on atolls necessarily introduce rat species. It is possible to compile from the literature quite an extensive list of shipwrecks which occurred in the Marshall Islands over the past 100 years. Yet, none of these vessels introduced any *Rattus rattus* and *Rattus norvegicus*; given the nature of some of the vessels it is highly unlikely that at least some would not have had rats on board (cf. Hezel, 1979). It would appear that the wrecks had all been stranded at locations where the rats could not get ashore or where they died in the surf when the vessels broke up.

The only clear evidence of colonisation by *Rattus rattus* and *Rattus norvegicus* in the Marshalls occurred when ships were moored at piers and where the rats had the chance to run down mooring lines or gangways. The dispersal of *R. rattus*/*R. norvegicus* is poised to increase as piers to unload the field-trip ships or fishing bases have now been constructed on many atolls. To contain the spread of these two species care needs to be exercised with lines being properly fitted with regulatory rat disks.

In order to avoid the accidental landing of shipborne rats on the bird atolls, however, *extreme* precautions need to be taken, both in view of landing or beaching any support vessels and in view of the unloading and lightening of the stricken (fishing) vessel.

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